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A Course in Physical Nature Study

FOR THE ELEMENTARY SCHOOL

BY

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INTRODUCTION.

A well known exponent of nature study defines the subject as being "a simple observational study of common things and processes."

The work outlined in this bulletin rigidly excludes abstract scientific generalizations and complicated apparatus, and is therefor *simple.* It insists upon the observational method, deals with the common things of life, and finally, lays emphasis upon *processes* as well as *things.*

The course comprised here is not a general nature-study course, but is made up of that much neglected branch of the subject known as physical or inorganic nature study. Experience has proved that children of the upper grammar grades take a more vital interest in the processes of inorganic nature than they do in the old-fashioned "object lesson" or in work which is exclusively biological. The difficulty of adapting material drawn from the sciences of physics, chemistry, physical geography, and astronomy, is considered so great by teachers that they are tempted to content themselves with the more objective material supplied by botany and zoology. A study of flowers and butterflies may suffice in the primary grades, but when the child's "what" changes to "why," we must put him into contact with some of the easily demonstrated laws of nature and let him feel that he is coming into a knowledge of the forces about him.

It is strongly recommended that the experiments and demonstrations suggested here be not neglected, for they are the life of the course. A little foresight in the matter of preparation and a very little expense at certain points will enable any enthusiastic teacher to accomplish all the work including the illustrative material outlined in the bulletin.

While it is true that there is material here which may be adapted to any grade from the primary to the high school, yet it is not advisable to give this work as a whole below the sixth grade, and the seventh or eighth grade is preferable for it. The time required to accomplish it is at least one hundred minutes a week for one year.

THE AIR.

A study of this substance so near to us and yet so little understood by children will serve as a good starting point in that large group of subjects classified as Natural Science.

To establish in the minds of the pupils the *reality* of this intangible thing may very well be the first subject to achieve.

Have the children fan the air into their faces with a book or paper.

Show by holding the finger over the outlet of a bicycle pump that the air has force to prevent the piston from being pushed into the barrel of the pump.

Show pressure of air, using a popgun.

Teach that wind is air in motion.

That air is in the earth as well as above it may be shown by dropping a large clod into a vessel of water when air bubbles will be seen to rise from the clod.

That air is in water also is shown by heating some water. Bubbles of dissolved air will form and escape long before the water is hot enough for steam bubbles to form.

Fishes breathe this air and would smother in boiled water.

The *pressure of air* is a property requiring demonstration.

Completely fill a glass or bottle with water. Lay over the mouth of the vessel a small piece of paper and quickly invert. The pressure of the air against the paper is greater than the weight of the water which is held up. Remove the paper and notice that as bubbles of air go in, the water goes out.

Pressure may be shown in a somewhat similar way by running a string with a knot on the end through a circular piece of leather (or rubber) and trying to pull the leather from a smooth wet surface. Unless the air gets under the leather, it can not be raised easily on account of air pressure on top of it. Emphasize that the force holding it down is pressure, not suction. Suction is not a force at all.

Star fish and other sea animals cling to the rocks by suction, but flies, contrary to the common opinion, do not.

The Barometer.—This instrument which depends upon air pressure is very useful in making clear some principles of the action of air.

Explain the barometer, and teach that it reads higher in low places because of the greater weight of the air above it.

Illustrate the weight of the air by piling up several books; place the

hand beneath them all, then place the hand under a few of them at the top of the pile.

At sea level the air is heavy enough to hold the mercury in the tube of the barometer about 30 inches high. Nine hundred feet higher the air holds the mercury about 29 inches high.

If the school has a barometer, take it to the highest and the lowest places accessible, and notice the exact difference in reading.

Calculate the difference in elevation between the two places, by means of this difference in readings.

Fig. 1.—A home-made barometer is an instructive piece of apparatus.

A barometer can be made very easily by sealing a glass tube rather smaller than a lead pencil and about 35 inches long. To seal, hold in a gas or lamp flame about two inches from one end and when the glass is soft pull off the end. This leaves the tube closed at that end. Fill the tube with mercury, using a medicine dropper, and invert it, while holding the finger over the end, in a small vaseline bottle of mercury. The tube must be entirely full before inverting so that no air will be left in it. About half a pound of mercury is necessary.

To invert the tube full of mercury in a small mouthed bottle into which the finger will not go, cover the end of the tube with a wide elastic band drawn tight to prevent the mercury from falling out of the tube. The rubber band may be removed as soon as the open end of the tube is below the surface of the mercury in the bottle.

The bottle and tube may be securely fastened now with string or wire to a board, the string to be passed through holes bored in it. A block for support may be nailed just below the bottle. A yardstick can be slipped in behind the tube as a scale. Set its zero end level with the mercury surface in the cup.

During the season of rains the children should become familiar with the use of the barometer, recording the readings with changing weather.

Gases in the Air.—Pupils should know something of the various constituents of the air and the uses of each. A few simple experiments are necessary to make these invisible substances realities to them.

(*a.*) *Water vapor.* If ice is obtainable, show the pressure of moisture in the atmosphere by the "sweating" of a cold water pitcher. Let pupils report evidences they have observed, as the formation of dew, fog, rain, etc., and the evaporation of water into the air.

(*b*) *Oxygen.* One fifth of the air is oxygen. Plants as well as animals would die without it. Fire must have it to burn at all. It is that which rusts iron and brings about decay. The easiest way to make oxygen for class experiments is to sprinkle a little sodium peroxide (from the drug store) upon water contained in the bottom of a jar or tumbler. Oxygen is rapidly set free from the chemical and fills the vessel, which should be loosely covered.

Hold a glowing splinter over the vessel and see it burst into flame. Fasten a small splinter to the end of a raveled picture wire. Light the wood and quickly introduce into a jar of oxygen. The wire takes fire and burns. Discuss conditions if air were all oxygen.

(*c*) *Carbon dioxide.* This gas though forming but a small proportion of the air is the chief food of all vegetation, being absorbed through the leaves.

The gas can be made in abundance by sprinkling cooking soda into a jar containing a little vinegar or other acid. Nothing will burn in it. Try a match or candle. It is heavy and can be poured from a jar into a tumbler. It will make lime water milky and is usually detected in this way. Pour some into a glass of lime water and shake it up. The water becomes white. Blow the breath, which contains much of it, through a straw or tube into lime water. Let a glass of lime water stand for several days exposed to the air; a white crust will form showing presence of carbon dioxide in the air.

CAPILLARITY.

Capillarity is the rise of liquids in tubes.

Select several tubes of different internal diameter and dip them into water. The water rises in all of them, but in the smaller ones it rises much higher. It has been found by careful measurement that the height of the water varies inversely as the diameter of the tubes.

Notice the shape of the surface inside the tube. Draw a picture of the tube and its contents. Is the surface concave or convex?

Put the tubes in alcohol. This does not rise so high. All liquids differ from one another in respect to capillarity.

Put the corner of a lump of sugar into water. Soon the whole lump is wet. The pores in the lump act as capillary tubes. Do the same with a clod of earth. Hang one end of a strip of blotting paper into ink. Put one end of a lamp wick into a glass full of water and let the other end hang in an empty glass. Allow to stand until the two glasses are about equally full.

Fill two cans or tumblers with mud. Weigh them carefully and adjust them so that they both weigh the same. Now set them in a sunny, airy place, and as soon as the surface begins to dry out, scratch up the surface of one of them with a match or toothpick, but let that of the other bake hard without being disturbed. Every day set them on opposite pans of the balance and notice that the one with a hard surface is becoming lighter than the other. Also weigh them frequently, seeing how much water each is losing. The experiment illustrates the fact that cultivating the soil after rain or irrigation tends to keep the water in; but allowing the ground to bake on top causes it to dry out. Why is this?

If the ground becomes hard and baked, the pores act as capillary tubes to draw the water to the surface where it can be evaporated. But if the surface is made loose by cultivation, the pores are made so large that they cannot draw the water up from below, and so it never comes up where the sun and wind can evaporate it.

Such a covering of fine dirt is called by farmers a "dust mulch." A mulch of straw or leaves has the same effect, namely, to keep the water from coming up to be evaporated.

THE SOLVENT ACTION OF WATER.

Dissolve salt, sugar, alum, etc., in water. Use an excess of the solid and stir well. The result is a saturated solution. (Give definition of a saturated solution.)

Pour off the clear liquid from each solution and heat it. Add more of the solid little by little. This shows that hot water is a better solvent than cold.

Pour into an evaporating dish (a tin cup), and boil off the water. Notice that the solid is left behind unchanged.

Evaporate to dryness in a clean white evaporating dish (or tin cup) some hydrant water. It also leaves some sediment, showing that it is not pure. Why is it not pure? Talk of the different substances in the earth over and through which the water has flowed before coming to the hydrant.

Other Solvents. There are some things which water will not dissolve but other liquids will. Put a lump of butter into water and another into gasoline or ether. Gasoline and ether are used to remove grease spots from cloth.

To Show that Gases are Dissolved in Water. Put water into a test tube and heat gradually. Bubbles can be seen coming off before it begins really to boil. These bubbles are air.

"Soda water" contains a gas (CO_2) dissolved in it in great quantities by means of ·pressure. When the pressure is removed, the liquid effervesces.

HEAT AND COLD.

As an easy transition from air to heat discuss the effects of heat upon air and other gases. Heat expands everything, but gases most of all.

Put a one-hole stopper, through which passes a glass tube, into a bottle. Dip the end of the tube into water. Nothing happens. Warm the bottle with your hands. Bubbles escape. Cool the bottle with water. The air contracts and water rises into the bottle.

Give an oral and a written account of all that was done, with reasons for each step.

Heat the bottle with a match or candle. The effects are magnified. Hold it in the sun or near a fire.

Ways in Which Heat is Developed.— (*a*) *By means of friction.* Have the children rub their hands vigorously together.

Rub a coin hard for some time upon the floor or a table, and pass to several pupils to report on its heat.

File a nail and pass it around the class.

Have the pupils report other instances of heat caused by friction.

Why is machinery oiled?

(*b*) *By chemical action.* Pour water over a cup of quick lime.

Teach that all chemical action produces heat, but that the degree of heat produced varies with the substances used.

Mention spontaneous combustion of oily rags.

(*c*) *By fire.* Explain that fire is rapid chemical action, and that the burning of some fuels produces more heat than is the case with others. Discuss different fuels used to produce heat and light.

Teach that fire is made by the uniting of a fuel with the air. Also that the new substances produced are carbon dioxide and water.

Hold a thick glass jar over a flame to show the moisture.

How Heat is Transferred.—Heat is transferred from one place to another in three ways: *Conduction, convection currents,* and *radiation,* or shining.

Hold a wire in the flame of an alcohol lamp. The heat of the flame runs slowly up the wire. This is *conduction.*

Put some sawdust in a test tube of water and heat at the bottom. The water when warmed rises, as can be seen by the movement of the sawdust, and heat is carried to the top. This is a *convection current.* Have pupils draw diagrams showing upward and downward currents by arrows.

Hold the hand beside a flame, not over it. The heat shines, or radiates, and warms the hand. This is *radiation.*

Hold the hand over the flame. The hot air rises to the hand. This is a *convection current.*

To Show that Some Things Conduct Heat Better than Others. Hold several wires of different metals (iron, brass, copper) in an alcohol flame. Which becomes hot farthest from the flame? Which is the best conductor? (Copper).

Hold one edge of a silver coin in a flame. See how very quickly heat is conducted to the farther edge. Silver is the best of conductors. Select a piece of any other metal similar in size to the silver coin (*e.g.,* an iron washer). Repeat the test and note the difference.

Non-metals are all poor conductors of heat. Hold broken pieces of glass, pottery, a glass tube, a stick, a stone, a clod, in a flame. They all conduct very badly, but some better than others,—stone better than wood, for example.

In Alaska and other cold countries stone can not well be used for building houses, for it conducts the heat from within to the outside so fast that it is difficult to keep the houses warm. A wooden house is warmer, for wood is a poor conductor.

To Show that Water is Heated by Convection, not by Conduction. Heat near the top a test tube filled with water. The bottom remains cool, for water is a poor conductor, and the warm water at the top, being lighter than the cold water at the bottom, cannot sink. When the flame is applied below, the water rises as fast as it becomes heated, and so the whole is warmed.

Heat Currents (Convection Currents) in the Air.—Strike a match. The flame rises. Why does it do so? The flame is made of heated gases in which are floating red-hot solid particles which give it its brightness and color. These gases being so hot are very light—less than half as heavy as the surrounding air, and for that reason they rise, just as light cork would rise in water which is so much heavier than it is.

Hold a large glass tube or a tall lamp chimney a few inches above a candle or alcohol flame so that the column of air in the tube becomes heated. Let loose small fluffy bits of cotton in the lower end of the tube. These are carried up, often to the ceiling. There is no upward motion within the tube until the air there becomes heated and so is made lighter than the outside air.

The longer the tube is the greater the force of the upward movement, for the same reason that the larger a piece of cork, the harder it is to hold it down in water.

The draught in a chimney or stovepipe is caused by the air within it becoming heated and therefore lighter. The higher the chimney the better the draught. Smokestacks on locomotives used to be made high, but now air is forced through the fire box and the smokestack does not need to be so high.

An easy and striking demonstration of the fact that heated air rises made be made by heating a flat iron or other piece of metal and then holding it in the sunshine at a window. Where the sunlight, after passing the metal, falls upon the floor or a wall or a large white paper held several feet from the iron the rapid upward movement of the heated air is convincingly shown.

Wind.—Some winds, not all, are the result of heat and cold. Just as a fire makes a movement in the atmosphere around it and in the chimney above it, so the heat of the sun may produce air currents which are called winds.

A good example of this is the "sea breeze." During the daytime, especially in summer, the land becomes warmer than the ocean; so the warm air over the land rises, being crowded up by the cooler air from the ocean which rushes in often at the rate of eight or ten miles an hour, forming a "sea breeze." At night the land quickly cools down until it is no warmer than the sea, and then the wind ceases to blow.

Sometimes, especially in winter, the land at night becomes much colder than the sea, and so during the night the wind blows to the ocean. This is called a "land breeze."

At the equator the air is heated by the tropical sun, and thus becoming lighter than the air on either side of the equator, it is crowded upward by the inrush of this air from the north and from the south. These two currents are called Trade Winds, because they are so constant that trading vessels can take advantage of them.

Examples of Radiation.—Hold a book or piece of pasteboard between the hand and a fire. Remove the screen suddenly and notice how quickly the heat reaches the hand. Radiation is almost instantaneous. The heat of the sun reaches us by radiation. It comes at the rate of 186,000 miles a second, reaching the earth in about eight minutes (500 seconds) after leaving the sun. (Divide 93,000,000, the distance in miles to the sun, by 186,000, to get this figure.)

Hold an electric light bulb in the hand and turn on the light. The hand instantly feels the warmth. It feels as if the globe were warm, but it is not, as may be seen by turning off the light before there has been time for the heat to be conducted through the glass. (If an electric lamp cannot be had, use a coal oil lamp, turning it up and down.)

Keeping Heat In or Out.—Why are some garments warm and others cool?

When we speak of dressing in warm clothing to keep out the cold, we mean dressing in clothing which is a poor conductor of heat and so prevents rapid loss of heat from the body. It keeps the heat in; it does not keep the cold air out. Cold is nothing but the absence of heat, just as darkness is simply the absence of light.

The body is always warmer than the air except on extremely hot days; so to keep warm we must keep the heat in, and to keep cool we must dress so as to let the heat of the body escape easily.

Woolen cloth is a poor conductor and therefore keeps the heat in. Cotton cloth is a better conductor and lets the heat escape more easily and rapidly.

Effect of Color in Clothing. So far we have spoken only of loss of heat by conduction. But when we are out in the hot sunshine, we need to be protected from radiant heat. For this, color is of more importance than material.

Lay two thermometers on a board and cover one with a black cloth and the other with a white cloth of the same texture and thickness. Black and white pasteboard may be used.

The one under the black cloth will run up faster than the other, for black absorbs radiant heat better than white. For this reason light-colored clothing is a better protection from the sun's heat than dark.

A black hat, even black straw, is a poor protection against the intense heat of the summer sun.

Red is almost equal to black as a heat absorber.

Building so as to Keep Heat In or Out. To have a house warm in winter it must be built so as to keep in the artificial heat. To have it cool in summer it must be built so as to keep out the sun's heat.

Air is a good non-conductor of heat. For this reason a "dead-air chamber" is left in the walls of buildings to "keep out the cold," or rather, to keep in the heat. The attic of a house also acts as a "dead-air chamber," and keeps the heat within from escaping as well as the sun's heat on the roof from being conducted through the interior. The house in this way is kept cool in summer and warm in winter. Why?

A metal roof is hot in summer and cold in winter because metal is a good conductor.

Ice houses. To keep ice from melting it is, of course, necessary to keep out the external heat. This is accomplished mainly by dead-air chambers. But an empty chamber is not sufficient for this, because, although heat would not be conducted across the empty space, still it would be carried across by convection currents. The chamber is packed full of some fibrous non-conducting substance which will entangle the air in its meshes and prevent convection currents. "Glass wool" and fibrous asbestos are used for this purpose.

Why is fur so warm? Fur is an exceedingly fine hair. Not only are the fibers fine, but they are set close together so that the air spaces between them are very small. The air is entangled in these small spaces and cannot flow in convection currents freely back and forth as it can through coarse hair. It is this entangled air which prevents the heat of the body from escaping.

All animals of frigid regions possess fine fur, while those of tropical regions have hair instead.

Feathers, like fur, are very warm, and for the same reason.

Wool and woolen cloth are much warmer than cotton, partly because the fibers, being finer and closer together, prevent free circulation of air, and partly because the fibres of wool are themselves poorer conductors than those of cotton.

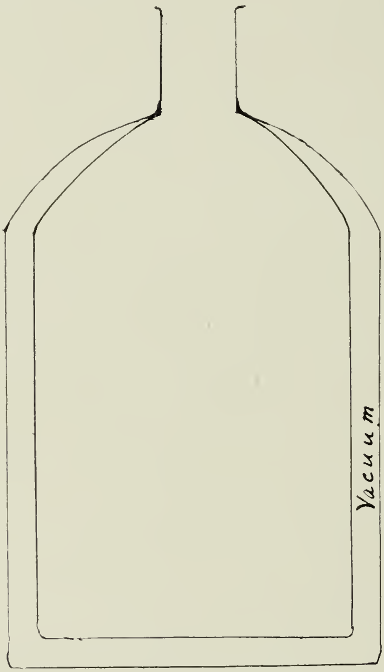

Fig. 2.—A thermos bottle. A vacuum prevents loss of heat either by conduction or convection currents.

The very best non-conductor is a perfect vacuum. It is used in keeping the heat from liquid air and other liquid gases. It is also used to keep ordinary liquids either hot or cold. See Fig. 2.

The liquid in question is put into a bottle which has a double wall, the air from the chamber between the walls having been removed as completely as possible.

Such a vessel is called a thermos bottle and is coming into very common use. Secure one if possible for experiments in keeping ice water cold and hot water warm.

Can heat pass by convection through a vacuum?

A vacuum has no effect upon the passage of radiant heat, but this would be slight, and to make it less the outside of a thermos bottle is silvered to reflect back the heat and prevent its entering the outer covering.

Freezing and Thawing.—*Temperature of freezing.* Stir a vessel of water with a thermometer and add ice till the temperature falls as low as it will. This is the temperature of melting ice. It is 0° C. or 32° F. Ice melts and water freezes at this temperature.

Freezing Mixtures. Mix salt and crushed ice in a cup and put the mixture into a test tube of water. Stir the ice, and the water in the test tube will freeze.

Take the temperature of the mixture of ice and water with a thermometer.

Why does salt mixed with ice make the mixture so much colder?

Before answering this question lay some salt (in lumps) on a cake of ice and notice how much faster the ice melts under and around each lump than it does elsewhere.

When ice melts it takes the heat which is used in melting it from its surroundings. This heat may be taken from the air or from anything near the ice. If a thermometer is put into the mixture of ice and salt, heat is taken from the thermometer itself, and it falls.

The faster the ice melts, the faster heat is removed from its surroundings.

When cream in a can is put into the mixture, the heat is rapidly taken from the cream by the melting ice, and the cream freezes as did the water in the test tube in the above experiment.

Expansion of Water in Freezing.—Fill a test tube with water and insert in it a one-hole stopper through which runs a glass tube. See that no air bubbles are left in the test tube. Immerse this tube in a freezing mixture of ice and salt. As soon as crystals of ice begin to form in the test tube, the water begins to rise, showing expansion.

After much of the water is frozen, warm the test tube in a flame or in the hands, and as the ice disappears the water falls, showing contraction.

The water really begins to expand 4° C. above the freezing point, for then, no doubt, the molecules of water begin to arrange themselves

in crystalline form, though the water does not become solid until zero is reached.

This expansion of water on freezing is a remarkable exception to the rule in nature. Almost all substances when melted occupy more space than when solid.

Melt a cupful of paraffine and then set it in cold water to hasten its cooling, and notice the great contraction as it solidifies.

Think what the result would be if water also contracted on solidifying to ice. It would become heavier than water instead of lighter as ice actually is, and would sink as fast as formed. This would allow more ice to form on top which in turn would sink, and this process would go on until the lake or river was full of ice. All the fish would be killed, and even the deepest lakes would soon become solid ice which could thaw only a few feet deep even in summer time.

There is one other substance which like water expands on solidifying. This is bismuth. Bismuth is a metal which easily alloys with other metals. Type-metal is an alloy of lead, bismuth, and antimony. Bismuth is used in order to make the letter expand and fill the mold in which it is made. Any metal other than bismuth would shrink away from the mold on cooling and so make an imperfect letter.

Bismuth expands 1/32 of its volume on solidifying; ice 1/11.

Artificial Ice.—Ice is usually made by the rapid evaporation of some liquid which evaporates easily.

Pour a little ether, or carbon-bisulphide, or alcohol, or gasoline on the hand and blow upon it. It feels very cold, for in order to be converted into vapor, it takes heat from the hand. The faster it can be made to evaporate, the more rapidly it takes heat from the surroundings and the colder they feel.

The above liquids do not evaporate rapidly enough to make ice, but there are liquids that do. Liquid ammonia (not a water solution of ammonia, but the gas compressed to a liquid) is the liquid usually employed. The pressure necessary to keep it in the form of a liquid is quickly removed and it evaporates so rapidly that the water surrounding it is frozen.

Liquid CO_2 is also used, and gives a much lower temperature than can be obtained with liquid ammonia.

Liquid air evaporating gives a still lower temperature, but liquid air cannot be made so easily.

A STUDY OF MACHINERY.

All kinds of machinery are made up of one or more simple machines. There are only a few simple machines: the lever, the pulley, the cog wheel, the belt and belt wheel, the inclined plane, the wedge, the screw, and the windlass are the principal kinds. See Fig. 3.

Each of these machines should be studied according to the following plan:

(1) Make the machine in question and demonstrate its action before the class.

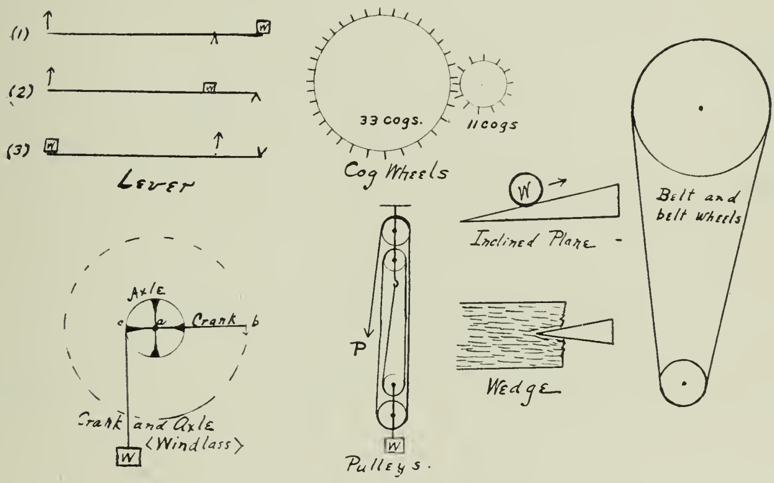

FIG. 3.—If pupils make simple diagrams of the machines, they will more easily under-understand their principles.

(2) Let the class give illustrations of as many pieces of machinery as possible in which it forms a part, as the lever seen in the pump and in the wheel barrow.

(3) Give the "law" of this machine,—that is, what is gained by using it. For example, how many times greater is the load to be lifted than the force used in lifting it. Thus, in using the lever, the load lifted is always as many times the power used as the power arm is times the length of the load arm.

(4) Work a few simple problems to illustrate this law.

The following are suggestions of the kind of problem that should be used during the discussion of each of the machines mentioned below:

The Lever. What load on a wheelbarrow can be lifted with a force of fifty pounds, if the load is one foot from the wheel and the hands four feet? (Ans. 200 lbs.)

The Pulleys. If five cords help to support a weight being drawn up by pulleys, how many pounds can be lifted by a force of 100 pounds? (Ans. 500 lbs.)

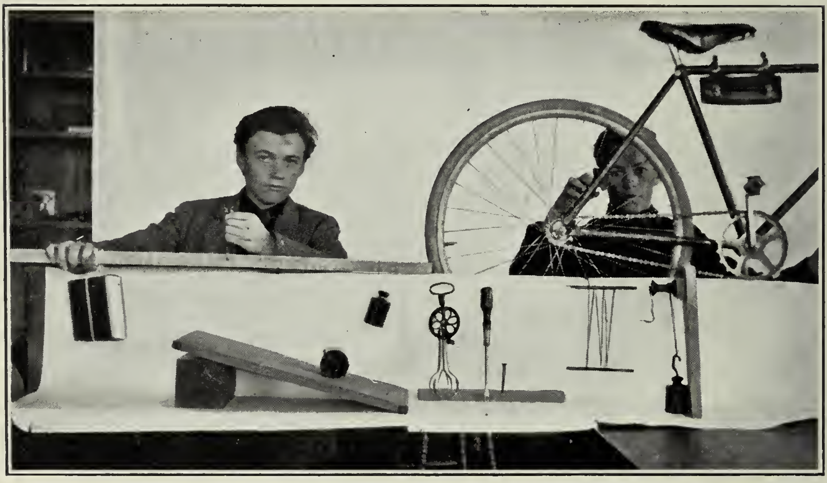

FIG. 4.—Examples of simple machines. The lever, the inclined plane, the cog wheels, the screw, the belt and belt wheels, the pulley (two pencils with a cord running back and forth between them), and the windlass.

The Cog Wheels. If the small wheel of an egg beater has eight cogs and the large wheel forty, how many times will the beater turn while the handle goes once around? (Ans. 5 times.)

The Belt and Belt Wheels. If the small wheel in Fig. 3 is 3 inches in diameter and the large wheel 18 inches, how many times will the small one turn for each revolution of the large one? (Ans. 6 times.)

The Inclined Plane. How hard will horses have to pull to draw a wagon up a hill which rises 10 feet in 100 feet, if the wagon weighs 2000 pounds? (Ans. 200 lbs.)

The Screw. If the hand moves 100 inches in turning a jack screw once around and the threads are ¼ inch apart, how many pounds can be lifted with a force of 20 pounds? (Ans. 8000 lbs.)

The Windlass. With an axle 6 inches in diameter and a crank 24 inches long, how heavy a weight can be lifted with a force of 10 pounds? (Ans. 80 lbs.)

The Lever.—Make a lever by laying a yard stick across some object which will serve as a fulcrum, and demonstrate that a heavy weight, such as a large book, may be lifted by using a very slight force.

Show that the lever may be used in three different ways; namely, by putting the fulcrum, the weight, or the power between the other two. These ways illustrate levers of the first, the second, and the third class. (See Fig. 3.)

The class should give as examples the crowbar, nut crackers, an ax when used in chopping, the claw hammer, scissors, a pump handle, sugar tongs, etc.

Teach the law of the lever as follows: The load to be lifted is as many times the power necessary to lift it as the power arm is times the load arm. (In all three kinds of lever, the arms are measured from the fulcrum.) In the eighth grade teach also that the product of the load arm times the load is equal to the product of the power arm times the power. Also, if proportion has been studied, that the load arm is to the power arm as the power is to the load.

Find by calculation the weight of a number of articles as follows: Support a yardstick at the middle by means of a string run through a small hole. Hang from any point on one arm by means of a string some known weight, say a pound, and on the other arm attach similarly some unknown weight. Slip the latter along until it balances, and then noticing its distance from the point of support, calculate its weight, using one of the three statements of the law of the lever as given above.

If this work be introduced below the eighth grade, require of the pupils only an approximate answer by making a mental estimate.

Hang a bucket on a pole between two pupils, and have them estimate or calculate the proportion of the weight that each lifts with the load at various points.

The Pulleys (Block and Tackle).—To represent the block and tackle in the simplest possible manner, place two lead pencils parallel about a foot apart. Tie a thread to one, and pass it back and forth between the two several times as a rope is wrapped around pulleys. Hold one pencil stationary, and allow the other one to move as the thread is pulled.

The action is similar to that of the pulleys, except that the friction is greater.

Teach that the weight to be lifted divided by the number of threads running between the pencils equals the power (provided there is no friction). This is the "law" of the pulleys.

Notice that the hand representing the power moves as many times as far as the load moves as there are cords between the pulleys.

Thus the gain in power is just equal to the loss in speed. This is true in all machines.

The Cog Wheels.—An egg beater or an old clock will serve to illustrate the cog wheels.

Show that cog wheels may be used to gain either speed or power, depending on the relative sizes of the wheels.

The number of cogs on the large wheel divided by the number on the small wheel equals the gain of power or speed as the case may be. This is the "law" of the cog wheels.

Belt and Belt Wheels.—The most convenient form of apparatus for demonstration will probably be the bicycle, in which the chain is a sort of belt and the sprockets are the belt wheels.

The law is that the speed gained is got by dividing the size of one wheel into the size of the other. In the case of the bicycle, the number of teeth on the sprockets may be taken as the sizes of the wheels.

The Inclined Plane.—This requires merely a short board, one end of which may be raised by laying it on a pile of books. Roll or slide some object up the board, pointing out the fact that the weight to be lifted is as many times the force required as the length of the board is times the height of the incline. This is the "law" of the inclined plane.

Give some problems, such as the force required to roll a 200-pound barrel up a board twelve feet long into a wagon three feet high.

Require diagrammatic drawings.

Explain that a 1 per cent or a 5 per cent grade means a grade rising 1 foot or 5 feet to the hundred.

The Screw.—As good an example as any of the screw is the vise. Let the distance between the threads be measured, and also the distance that the hand moves in turning the lever.

The latter divided by the former will give the number of times the force is multiplied by the use of the instrument. ("Law" of screw.)

Discuss the resistance to be overcome and the approximate gain in power in the case of the ordinary screw, the jack screw, etc.

The Windlass.—A spool revolving on a nail driven into a board with a strip of wood a few inches long tacked to one end of the spool for a crank will illustrate this machine.

Show how easy it is to lift a weight by means of it.

Give the rule for finding the power gained. The power gained is equal to the diameter of the axle divided into double the length of the crank. ("Law" of windlass.)

LIGHT.

The Sources of Light.—Begin the topic of light with a conversational lesson on the sources of light. Let the pupils suggest the sources and discuss each.

(*a*) The sun, the principal source.

(*b*) The stars. These are suns like our sun but so far away that they seem dim.

(*c*) The moon-reflected sunlight.

(*d*) Fire of all kinds including gas light and lamp light.

(*e*) Red hot or white hot substances. This includes electric lights, both the arc light and the incandescent (bulb) light.

All bodies begin to glow with a red heat at 525° F.

(*f*) Phosphorescence. Instruct the pupils to wet a match and rub it gently on something in the dark and to report results.

(*g*) So-called "phosphorescence" of certain forms of animal life. The firefly is a notable example. The light of the firefly is made at will and without apparent heat. The phenomenon known as phosphorescence in the ocean which produces a flash of brilliance at each dip of the oar and causes fish to leave a bright trail behind them as they dart through the water, is the result of millions of microscopic living organisms called *noctiluca*. These become abundant only at certain times of the year.

Speed.—Awaken curiosity among the children to know whether light requires any time in which to travel.

Would a light made at a distance be instantly seen?

If a window shade several miles away were suddenly drawn at night, would the light within reach a watcher instantly,—that is, would you see the light as soon as the curtain was drawn?

It has been found by experiments somewhat similar to the above that light takes time to travel any distance, but that it goes with such great velocity that, could it go in a circle, it would travel seven times around the earth in a second.

How fast does sound travel?

Why do we see the flash of a gun before we hear the report?

Reflection.—What is echo? What is reflection?

Use a mirror to reflect sunlight, showing that in order to throw

the light back toward the sun, the light must fall perpendicularly upon the glass.

Turn the mirror so as to cast the reflection to one side and show that the angle or slant at which the light strikes the mirror is equal to the angle or slant at which it leaves the mirror.

Prove the same fact by holding the mirror so that it will face the class and letting them see that those directly in front of it can see their own reflection in it. Those on one side can see those on the other.

Represent these facts in a diagram.

A rubber ball will obey the same law in rebounding. Try the experiment.

The force of gravity prevents the ball from perfectly obeying this law.

Does gravity affect light? Why not? (Light is not a substance.)

Reflectors. Mention as many things as you can that are good reflectors.

Almost any surface will reflect if smooth enough. For example, polished metal, a varnished table top, cloth worn smooth, an unruffled pond.

Diffusion.—Light coming from a rough object is said to be diffused, not reflected. The rough surface scatters the light in all directions because the rays strike the particles composing the surface at all angles. As they are not thrown off at any one angle, no image is formed. If the surface of glass is roughened by grinding, light does not shine straight through it but is diffused in all directions so that we cannot see any objects through it.

Define the words *translucent* and *transparent.* Almost as much light shines through translucent glass as through that which is transparent.

Refraction (bending).—Show by putting a pencil into a cup of water that it seems to be bent.

Teach that it is the light, not the pencil, that is bent.

Light is always bent when passing through a surface except when it passes through perpendicularly.

The bottom of a cup seems to be raised by pouring in water.

A pencil held behind a thick piece of glass seems to be set off to one side of its true place when viewed at an angle.

Indians learn to throw the spear in spear-fishing lower down than the apparent place of the fish.

When light is bent (refracted), it is also separated into colors, but this separation is often so slight as not to be noticeable.

If a prism can be secured, illustrate with it both bending and separation into colors.

Color.—Make and study as varied a collection as possible of colors and shades of color.

Discuss differences of similar tints.

Hold a prism in the sunlight so that the spectrum formed will fall upon the ceiling or wall.

The prism separates the light into these colors.

Teach that light is made up of all the colors. When mixed as they are in sunlight we see none of them. But the prism separates them and puts them side by side. These colors are called the spectrum.

How many separate colors can you see in the spectrum, or in the rainbow, which is a spectrum made by drops of water in the air?

We see any colored object by means of that color which it reflects to us.

White reflects all the colors and black none of them. Black, then, is the absence of color. An object reflects no light if perfectly black.

To illustrate the last statement, make with an eraser or moist cloth a clean spot on the blackboard. The rest of the board in contrast to this spot looks far from black. It reflects some light. The spot will appear, especially to one with half-closed eyes, like the entrance to a dark cave. It reflects practically no light.

Images.—If light from an object passes through a lens or through a small hole, an image will be formed.

Make a hole as large as a pencil through a piece of cardboard. Darken the room as well as possible, and hold the cardboard between a lighted candle and a piece of white paper, each a few inches from the card. An image will be seen on the paper.

If a lens can be had, substitute it for the perforated card; and if the distance be varied suitably, an image much clearer than that of the first experiment is secured.

In this way is an image formed in the camera. In taking a photograph this image is made permanent.

SOUND.

See Higgins, "First Science Book," p. 91, or any text-book on Physics.

Vibrations.—Strike a bell and gently touch the edge with the finger-tips to feel the vibrations.

If a tuning-fork is at hand, it may be used in the same way, and also

Fig. 5.—A convenient and effective sonometer. Wire stretched across a door, which acts as a sounding board.

may be plunged into a glass of water while sounding to make the vibrations visible.

Stretch a string or wire and pluck it, so that the vibrations may be both seen and heard.

This may be done very satisfactorily by fastening one end of a wire,

such as is used on brooms, to the hinge of a door, passing the other end around the door knob and drawing it tight with the hand. When the wire is made to vibrate, its tone is greatly reinforced by the door, which acts as a sounding-board.

Vibrate a yard stick, pointer, or some such article, by laying it on a table and holding it firmly with one end projecting far enough to make a good tone.

Using a stringed instrument of any kind, show that as long as the tone continues the strings are vibrating.

FIG. 6.—Experiments in the transmission of sound. A pasteboard megaphone, a garden hose speaking tube, a long pole to show that solids carry faint sounds better than air does, a rope to show waves.

The sound made by a humming-bird is caused by the vibration of its wings.

There must be at least sixteen vibrations per second to produce sound.

How Sound Travels.—Hold a yardstick or long pole with one end to a child's ear. Scratch the other end slightly. Take it away from the ear and make the same noise. Sound does not travel so well in air as in wood.

Sound travels in waves through air or other substance.

Discuss water waves. Does the water move forward as far as the wave goes?

Lay a long rope on the floor or ground. Fasten one end of it, and taking the other end in the hand, send a wave along it while it touches the floor. Notice that the tighter the rope is stretched the faster the wave travels. The stretching makes the rope more elastic; that is, it flies back into position more quickly after being bent.

Sound travels fifteen times as fast in an iron railroad track as in air because the iron is more elastic than air.

Does the fact shown above that sound travels with more force in wood than in air prove that it also goes faster in the wood?

FIG. 7.—Velocity of sound. A ten-inch pendulum vibrating half seconds measures the time necessary for the return of an echo of a sound made by clapping two boards together.

The String Telephone (see Higgins "First Science Book," p. 96.) Connect two tin cans by means of a strong string about 100 feet long. Stretch the string tightly and talk into one can while some one listens at the other. If the string is run out through an open window, one person may talk into the outer can, while all in the room may hear the sound as it comes from the can within. Take care that the string touches nothing and is tightly stretched.

Sound waves pass along the string. This is in no way similar to an ordinary telephone, for there no sound goes over the wire, but an electric current which reproduces the sound at the other end.

The Speaking Tube.—Let one pupil talk into one end of a long garden hose, the other end being brought around the corner of the house or through a window. All near this end can hear the words as they come from the tube.

In this case the sound waves are not allowed to spread in all directions, but are confined to the air within the tube.

The Megaphone.—Make a megaphone of pasteboard. Let one pupil speak through it from a distance. The megaphone directs the sound forward in one direction.

Speed of Sound.—With the class out of doors find how far sound will travel in a second.

Make a pendulum which will vibrate half seconds by tying a stone to a string ten inches long. Send a pupil walking away from the class with two boards to clap together. Let him stop from time to time and clap the boards. Release the pendulum as the boards are seen to strike. Let the boy go on until it requires the time of two swings of the pendulum for the sound to reach the class.

Later have two pupils measure this distance and report to the class. It should be about 1100 feet.

Interest the pupils in finding the velocity of sound by timing sounds at great distances, such as steam whistles or the firing of guns or cannon. A watch with a second hand should be used. The time elapsing between seeing the steam from the whistle and hearing the sound gives the distance. Each second represents 1100 feet, or five seconds a mile.

Velocity in Iron. If a car track having the rails exposed down to the ties is within reach, take the class to it, and by striking the rail two or three hundred feet distant from your pupils, you will produce two successive sounds, one coming through the rail and the other through the air. (If earth is filled in against the rails, the vibrations are deadened and sound will not travel.)

The distance to a flash of lightning can be found by counting the seconds between the flash and the thunder clap and multiplying this by five, since sound travels about one fifth of a mile (1100 feet) per second.

Echo.—Take the class to a point opposite a flat wall, such as the side of a house. Make sharp sounds—for example, by clapping two boards together.

Find how close to the wall the sounds may be made and yet give an echo. If too close, the echo and the original sound are so nearly simultaneous that they appear as one.

Why do large rooms echo more than small ones? (Sound and echo are not simultaneous.)

Why is a flat wall better than an irregular one?

Why do we need to be directly opposite the wall?

Make the sound at an angle from the wall and see where the pupils must be to hear the echo.

Stand between two houses and notice a double echo.

Go into an unfurnished room and listen to the many confused echoes.

Reverberation of thunder in the mountains is caused by the sound re-echoing back and forth from mountain sides.

Why does furniture in a room help to prevent echo? (The sound waves are broken up as water waves are by rocks projecting from the surface.)

MAGNETISM.

To perform experiments a magnet, costing about 20 cents at a hardware store, is necessary.

What a Magnet will Attract. Show that nothing but iron and steel are attracted. Try many metals and use the occasion to call attention to the metals, their names and uses.

FIG. 8.—A home-made electromagnet lifting shingle nails. (A few cents worth of small magnet wire wrapped on a bolt or large nail.)

Test pins, needles, pens, wire, etc., to see if made of iron or steel.

Making Magnets. Any piece of hard steel, as a knife blade, a needle, or a pen, may be magnetized by rubbing it on a magnet.

Rub one end of a needle on one pole of the magnet, then turn it about and rub the other end on the other pole of the magnet.

Magnetize a number of needles thus and float them on a large pan of water on thin disks of cork.

If the points of all the needles have been rubbed on the south pole of the magnet, they will be north poles and will point north, acting as compass needles.

Action of Poles Upon Each Other Show that when the points (north poles) are brought near to each other in the water, they repel each other.

Show that the same is true of the eye ends.

But when a north and a south pole are brought near to each other, they draw together and hold.

Bring successively the north and south poles of the magnet near to the ends of the needles. Predict in each case what the result will be.

Summarize the facts illustrated above as follows: Like poles repel each other and unlike poles attract.

Break a needle in two and show that it is now two magnets with a pole at each end. This would be the case were the needle broken into any number of pieces.

Show by lifting small articles, such as tacks or iron filings, that the greatest strength of the magnets is near the end (at the poles).

Put the magnet on a table and lay over it a piece of white paper. Sprinkle iron filings on this to show the "lines of force" which surround a magnet.

It will be seen that the force is not in the magnet alone but around it.

If one end of a nail is held very near to the pole of a magnet, it becomes for the time a magnet and will pick up bits of iron. When the magnet is removed, the nail loses its power.

Electromagnets. Wrap a fine insulated wire a hundred times or more about a large nail or bolt. Pass a current from a battery of several cells through the wire and the nail will become a magnet. It loses most of its magnetism when the current is stopped.

This principle is used in the electric bell and many other electrical instruments, as explained below where these instruments are described.

ELECTRICITY.

Material Required: An electric bell, 45 cents; 10 cents worth of small (No. 25) magnet wire; a dry cell, 30 cents (or a number of worn-out dry cells which can be revived as indicated below).

This newest and most important science should form a part of a nature study course because of the interest which children, especially boys, take in the subject. Many of the applications of electricity, such as lighting, heating, and bell-ringing, are as intimately concerned in the life of the girl as of the boy, and being a matter of daily observation, deserve a place in the nature study course.

In order to make any study of electricity profitable, some electrical apparatus is essential. As nearly every school has one or more boys, even as early as the fifth school year, who are interested in electricity and have made and collected electrical material of various sorts, all that is needed can often be secured through the pupils.

The first necessity will be a few battery cells and a little wire. Worn-out batteries may be secured in abundance from a garage. These may be put into fairly good working order by punching a number of holes in the zinc coating and setting them in cans of water. The cans must not touch. They often work well enough without any treatment.

Insulated wire is inexpensive and should be used, but ordinary broom or clothes line wires will serve the purpose, if not allowed to touch each other.

A study of the cell itself is the first thing to undertake.

The "dry cell" consists of a zinc plate (the container itself), and a carbon plate (the rod in the center), and a moist substance packed in between the plates.

Take a dry cell apart.

Most cells contain a liquid instead of the moist solid of the "dry cell."

All cells are essentially the same, having two plates of different material and a liquid between.

Let pupils find out all they can of materials used in different batteries and report in class.

In almost all cells one plate is zinc. The second plate is usually either carbon or copper.

The liquid used may be salammoniac, or sulphuric acid, or chromic acid. Other chemicals are used in some cells.

Any two metals in almost any solution would give *some* current.

Several cells connected form a battery.

There are two ways of connecting cells, in "series" and in "parallel."

If all the zinc plates are connected and all the carbon plates are connected, the connection is in "parallel."

But if the zinc of each is connected with the carbon of the next cell, the result is connection in "series."

Series connection is usually best.

If a bell can be secured, ring it with one cell, then connect several cells, and notice difference in the loudness of the ring.

A bell on the wall may be connected with a battery on the floor. The bell is so typical of many electrical instruments that one should be purchased if possible for the use of the school. The cost is 50 cents or 75 cents.

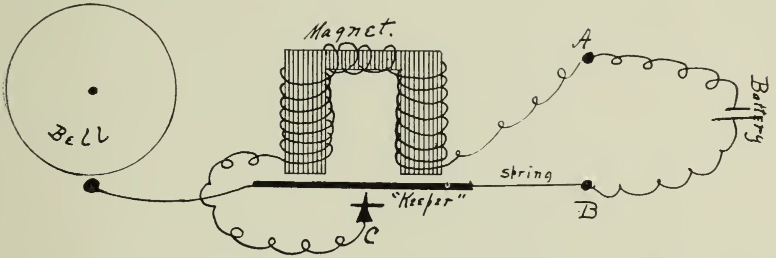

FIG. 9.—The electric bell, showing the essential parts and the course of the electric current.

The Bell.—Before making an explanation of the bell, refer to the experiment above in which a current in a coil of wire wrapped around a bar of iron, such as a nail or bolt, will make a magnet of the bar. While the current is flowing, the bar will pick up iron filings or tacks, and attract knife blades or other small pieces of iron.

Start and stop the current several times, noticing that the bar loses its magnetism when the current is broken.

The electric bell has an iron bar wrapped with wire, and when the current is started this becomes a magnet and draws the iron tapper against the bell. When the tapper moves, however, it makes a gap which breaks the current, and the iron ceases to be a magnet and the tapper springs back into place. The gap is now closed, the current starts again, and another tap is given. This process repeated makes the tapper sound continuously.

The bell's action may be more easily understood if it is analyzed into successive steps as follows:

(1) The current flows from the battery to the thumbscrew or "binding post" A, Fig. 9 and around the iron spools, making the iron into a magnet.

(2) This magnet instantly draws the iron "keeper" to itself, making the tapper which is fastened to the "keeper" strike the bell.

(3) As the keeper is drawn to the magnet, it leaves a gap between itself and the metal point C, thus *stopping* the current.

(4) The current being stopped, the magnetism is destroyed and the keeper is thrown by the spring back against C, thus allowing the current to start again.

(5) The whole process is now repeated, causing another tap. Constant repetitions cause the bell to ring continuously.

The Push Button.—This is a means of closing a gap in the wire circuit, thus allowing a current to flow.

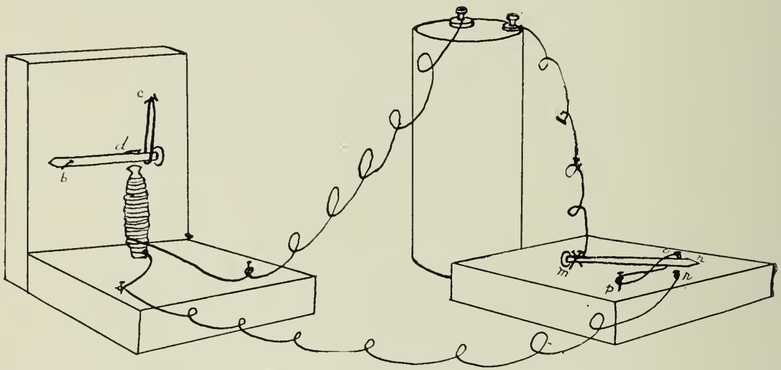

Fig. 10.—Telegraph apparatus made at an expense of ten cents. Two houses may be put into telegraphic communication by means of fence wire.

The Telegraph.—A very good telegraph sounder may be made by any boy at an expense of five or ten cents for insulated wire.

A small bolt is wrapped with several hundred turns of fine (No. 25) magnet wire, and the end of the bolt is put into a close-fitting hole bored in a board as shown in Fig. 10. An upright board is nailed on back of this bolt, making a convenient place to attach a tapper which consists of a large nail. This is supported at one end on a small nail, *b,* and at the other by a rubber band hung from a nail *c*, so that the tapper and the nail are about one thirty-second of an inch apart. A small nail *d* serves to make the tap double, as it should be.

A "key" to use with this sounder is made as follows:

Into a board three or four inches square drive a small nail at *m*, Fig. 10, to which a long nail *mn* is fastened with a wire. This nail is held up (so that one end is about a quarter of an inch above the board) by means of a twisted rubber band stretched between the nails *o* and *p*. It is pressed down with the finger until it touches the nail head *r* to which the battery wire is attached, thus making connection so that the sounder clicks.

One or two good dry cells or three or four old cells soaked up in cans of water will operate the instrument well.

The key and battery can be placed on one side of the room and the sounder on the other, or in another room; they can be connected with any sort of wire, (not necessarily insulated). Pupils can connect two houses a short distance apart in this way provided the wires do not touch the ground.

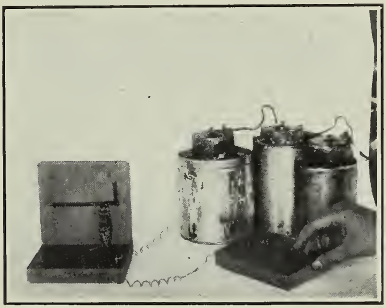

Fig. 10*a*.—Telegraphic instruments shown by diagram in Fig. 10. A good piece of manual training work for boys.

The key in a sender's office is similar to the push button used for door bells. It closes a gap and allows the electricity to flow.

Each tap of the operator sends a current to the sounder in a distant city. The sounder is similar to a bell. Each time a current is sent into it, it becomes a magnet and draws the tapper down. A bell serves excellently as a sounder if used as described below.

Connect the bell at one end of the room with a battery of two or three cells at the other end. The connection is made by means of two wires. Have a gap in one of the wires near the battery which can be closed by touching the cut ends to serve as a sending key.

The bell may be made to tap like a telegraph sounder by connect-

ing the screw "C" back of the tapper with a binding post "B" by means of a short wire. See Fig. 9.

The Electric Light.—Show the class an incandescent electric bulb. Note how the two ends of a carbon fibre are fastened to two wires which are sealed into the glass. The current goes in on one of these wires, passes through the carbon fibre, heating it red hot, and passes out over the other wire.

If air could get into the bulb, what would happen to the carbon?

If you have a burned-out bulb, break it to show the effect of letting air suddenly into a vacuum.

Since the invention of the tungsten filament, to be used instead of carbon, a great saving in electricity can be made by its use. Tungsten is a metal which is capable of giving more than twice as much light as carbon, using the same amount of electricity.

Arc lights used for street lighting have two carbon rods held about a quarter of an inch apart so that the current must jump across the gap. In doing so it heats the ends of the rods to about 3800 degrees, the highest temperature known on earth. (The sun's temperature is thought to be about twice that.)

Frictional Electricity.—Small amounts of electricity may be generated by rubbing together certain substances.

To be successful with these experiments, you must have very dry weather. A "desert day" is best.

Rub a stick of sealing wax or a fountain pen (hard rubber) with a woolen cloth; or rub a piece of glass (a lamp chimney) with a silk cloth (silk coat lining). A genuine rubber comb run through the hair several times will serve the purpose.

Fine bits of tissue paper will be picked up by either the sealing wax, glass, or rubber comb.

It is this sort of electricity that the frictional machines generate for X-ray work.

Discussion of Other Applications.—Although it is impossible in the elementary schools to perform elaborate experiments in electricity, it is desirable that every child whether he is to go into science in the high school or is to leave school, should leave the grades with some definite idea of the uses of electricity which are so intimately connected with the life both of the boy and the girl.

There are often boys in the class who have gained a large amount of information from their practical experiments and observations, and may be interested and stimulated by a discussion which goes farther

than is within the province of the school to demonstrate with experiments.

If it is possible to arrange with the manager of a garage or power house to have the children taken where electrical apparatus can be shown them and explained by those in charge, it will be very instructive and interesting.

A talk by a practical electrician after the class has been given the principles of the subject will carry them farther than it would be possible for the teacher to do.

Following are some of the subjects which might well be discussed and perhaps illustrated by pictures or excursions to shops.

(1) The electromagnet used for lifting heavy iron. This is a magnet similar to that found in the bell except that it is very large and is fastened to a crane. It is employed in foundries and in loading cars. The end of the magnet is brought against an iron boiler or keg of nails, for example, the current is turned on, when instantly the iron adheres to the magnet and can be lifted by the crane. When it is desired to let go, the current is turned off. The magnet is sometimes used for a broom to sweep up scrap iron on the floor of a foundry.

(2) *Electric Heaters.* In these the principle is similar to that of the incandescent bulb, that is, the wire through which the current is made to pass in the instrument becomes very hot. Examples are the electric toaster and the electric flat iron. If these can be brought (by a pupil, perhaps) and shown the class they will be better understood.

The most significant thing about such heaters is that the wire in the heater becomes hot and that in the cord leading to it there is no heat. The reason is that the heat is developed only where there is great resistance, and the wire used is of different material from that used in the cord and offers more resistance to the flow of the current.

About eight or ten times as much electric current is used in a toaster or flat iron as in a sixteen-candle power light.

(3) *Electric Motors and Dynamos.* A dynamo is an instrument which if turned will generate a current.

A motor is an instrument which will turn (and will make other machinery turn) if a current is run into it. The details of construction must be left for the high school.

Let pupils give uses of a motor,—for example, to run a street car, an electric automobile, a sewing machine, many kinds of farm machines, (such as a cream separator, an irrigation pump,) the suction pump in a vacuum cleaner, the electric fan, and a great variety of saws, lathes, etc., in a machine shop.

(4) *Spark Coils for Automobiles and Other Gasoline Motors.* All gasoline motors are run by the force of successive explosions of gas which take place in the cylinder. Each explosion is caused by an electric spark igniting the gas. A battery is not strong enough to give such a spark, and so a spark coil is used. This is made of a double spool of wire, one spool slipped inside another. The outer spool has one hundred or more times as much wire as the inner spool, sometimes several miles of it. The current from a battery of several cells is run into the inner coil. This generates a current in the outer coil which has more force than the battery current has and is capable of giving sparks.

(5) *Electroplating.* Plated silver ware is made by immersing ware made of some cheaper metal in a bath containing a silver solution. A bar of silver is placed in the bath near the things to be plated, and then a current is passed from the bar to the metal ware, through the solution. The current dissolves away the silver of the bar and carries it through the solution and deposits it evenly all over the spoon or whatever the ware may be.

(6) *The Transformer.* Why are men working on light and power lines sometimes killed by touching a wire, while accidents seldom occur in houses lighted by electricity which comes from these lines? Within a few hundred feet of every house where current is used may be seen a black iron box on top of a pole, from which the wires come supplying the houses near by. These boxes are transformers. They reduce the force of the current so that it is safe to use. The *amount* of current is not decreased to any extent by the transformer, but its *force* is lessened. It would not do to transform it at the power house for the whole city at once, because it needs its force to carry it for long distances through the wires.

The spark coil used in automobiles is a kind of transformer; but instead of making the force less, the spark coil makes it greater.

(7) *Wireless Telegraphy.* A wireless telegraphic apparatus consists of a sender which is a very powerful spark coil, and a receiver which is an aerial wire to which is attached an instrument so delicate that it will respond to a very little electricity.

The spark coil sends out waves of electricity in all directions like the waves of sound sent out all ways by a person's voice. The waves of sound can be caught by a person in any direction—similarly the waves of electricity can be caught by any one who has a receiver.

Just as an ear trumpet catches more of the sound than the ear alone, being bigger, so the aerial catches more of the electric wave than the little instrument in the receiving office could do alone.

ASTRONOMY.

Astronomy may seem at first thought too difficult a science from which to draw material to be used in nature study. Very naturally a teacher untrained in astronomy will feel that a subject so vast and intricate is more fitted for the college student than the elementary pupil. But this science which has been studied from the infancy of the race is full of inspiration and stimulus for the infant mind today.

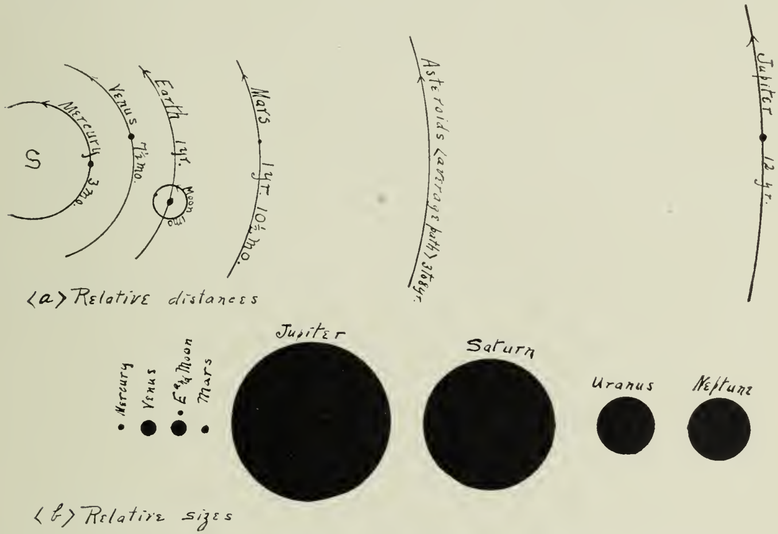

FIG. 11.—The planets. In (*a*) is shown their orbits and their relative distances from the sun. In (*b*) relative sizes.

The only equipment the teacher needs is to become herself interested in astronomy and to have sufficient guidance in the selection of material suitable for children.

The following suggestions are made to supply the latter need.

The Solar System.—The first step to take in order to lead the child's mind out beyond the earth is to give him an idea of the solar system. Illustrations are needful to this end; verbal description will not suffice.

The simplest illustration is the blackboard drawing. A series of concentric circles representing the orbits of the planets about the sun should be placed by the pupils in notebooks kept for such diagrams and for notes.

No diagram of the sort can be made to represent correctly all the relationships of size and distance. Like a raised map, it is intended to be suggestive rather than accurate as to scale.

By means of a number of diagrams each intended to present one fact, it is quite possible to work to scale and thus give correct proportions.

For example, the relative distance of the planets from the sun should be shown thus:

Place at one end of the blackboard a dot for the sun. A dot 5 inches from this will represent Mercury. Venus is shown by a dot $8\frac{1}{2}$ in. from the sun, the earth, 12 in., Mars, 1 ft. 2 in., the asteroids, 2 ft. 9 in., Jupiter, 5 ft., Saturn, 9 ft. 6 in., Uranus, 19 ft., Neptune, 30 ft.

By curved lines show portions of the orbits; the time of one revolution about the sun (one year of the planet) may be written on each. See Fig. 11.

Another set of relationships among the planets is that of size.

Let a permanent illustration of this be made by cutting from paper a set of circles, the diameters of which represent respectively the diameters of the planets. These may be pasted on the blackboard in the order of the planet's distance from the sun, thus serving to teach both size and order of the planets.

Convenient sizes for these circles are as follows: Mercury, $\frac{3}{8}$ inch; Venus, 1 inch; earth, 1 inch; Mars, $\frac{1}{2}$ inch; Jupiter, 11 inches; Saturn, 9 inches; Uranus, 4 inches; Neptune, 4 inches.

The height of some object in the room, as for example, the door and its transom, may be selected to represent the diameter of the nine-foot circle requisite to show the size of the sun upon the same scale.

An easily made model which makes the relative positions and motions of the solar system objective is shown in Fig. 12.

The sun is represented by a ball *S*, suspended by a string as shown, and anchored to the floor so that it will be stationary. *E* is a smaller ball representing the earth. *P* represents any other planet, and *M* the moon. The whole being attached to the ceiling by means of the cord *cd*, is made to revolve about the center *S*. The moon makes several revolutions about *E* while *E* passes once about *S*—several months to each year.

Rotation of the planets and the sun is also seen.

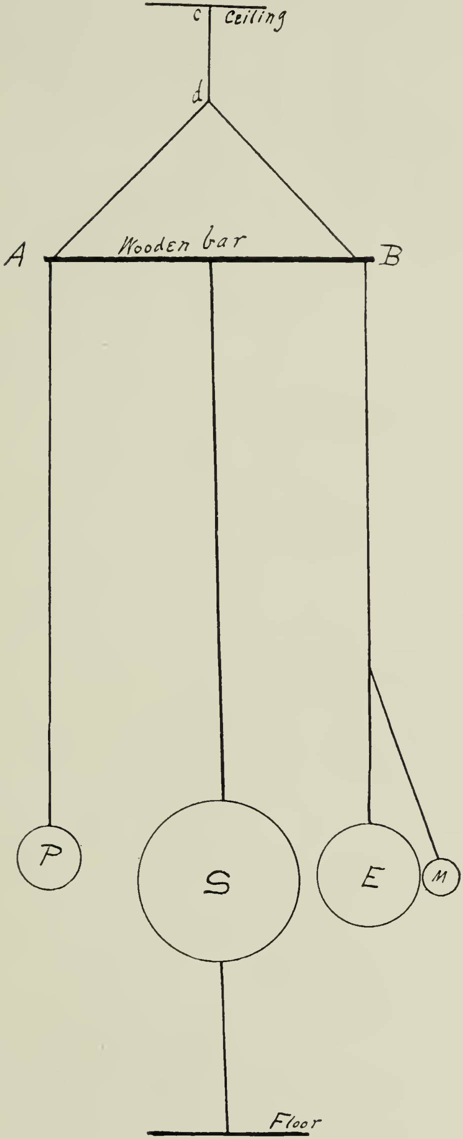

FIG. 12.—A model of the solar system.

P may be made to revolve in a smaller circle than *E*, representing Mercury or Venus, or in a large circle, representing one of the outer planets.

The Sun.—After a clear conception of the solar system as a whole has been gained, some time should be given to the consideration of each member of the system, especially of the sun.

When we have learned the sun's distance from us, 93,000,000 miles, its size can be determined easily by the pupils in the following manner:

Darken the room as thoroughly as possible. Draw down the shades. Make a pinhole in one shade so that the sun can shine through on to the floor, or, better, on a piece of white paper held 4 or 5 feet from the pinhole. The circular spot of light is the image of the sun.

The diameter of this image divided into its distance from the hole in the shade is equal to the diameter of the sun divided into its diameter. Thus using the distance of the sun, 93,000,000 miles, it is easy to find that the diameter of the sun is about 866,000 miles. See Fig. 13.

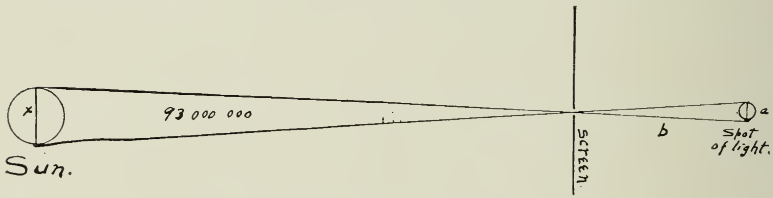

FIG. 13.—Measuring the size of the sun. The diameter of the spot *a* is to the distance *b* as the sun's diameter is to 93,000,000.

Such images of the sun are a familiar sight upon the ground in a forest. The openings among the leaves correspond to the pinhole of our experiment.

Another observation to be made upon the sun is for the purpose of finding its apparent motion north and south throughout the seasons.

Measure the length of the noon time shadow of a house or other object from week to week and note the changes in length. This is a simple method of testing the seasonal motion.

A more instructive method may be shown by means of apparatus made as follows: Into a board about a foot square drive a nail near one corner. See Fig. 14. Describe a circle about the nail as a center and divide the circle into degrees. The shadow of the nail at noon falls across the circle at a certain point depending upon the position of the sun. The figure at this point gives the distance of the sun south of us.

The distance from our zenith to the equator is given by our latitude.

Thus the distance of the sun north or south of the equator is easily found.

In the diagram (Fig. 14) the shadow at 56° shows that the sun is 56° south of the observer's zenith. Suppose the observer to be in latitude 32½°, then the sun must be 23½° south of the equator, —56° minus 32½°.

This will be the condition on the 22d of December.

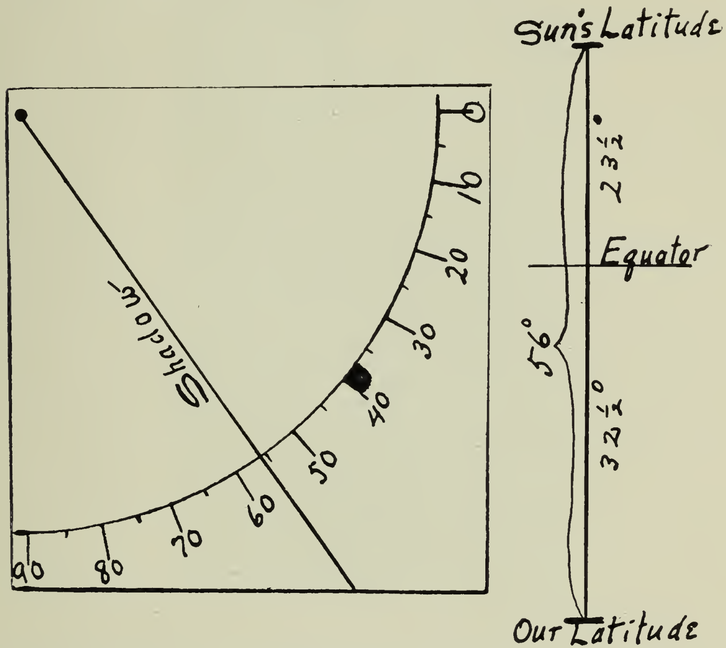

FIG. 14.—A "sun board." The reading at noon shows how many degrees the sun is to the south of us. Daily readings show sun's apparent motion north or south.

In this manner the class can find the position of the sun on any day in the year.

Especial observation should be made of the equinoxes and solstices.

The cause of this apparent motion of the sun can be shown by a simple demonstration.

Use a sphere to represent the earth (a small globe will do or an apple with a pencil circle to mark the equator). Let a pupil stand to represent the sun. Pass the sphere around the child, keeping the axis tilted $23\frac{1}{2}°$ (approximately) from the perpendicular and pointed always in the same direction. It will be seen that in one portion of

FIG. 14*a*.—"Sun board" shown by diagram in Fig. 14.

the circle the child is looking (the sun is shining) directly upon the equator; in another portion he is looking upon the part above the equator; and in a third upon the part below the equator.

Day and Night.—Using a globe, a series of demonstrations may be made which cannot fail to be helpful in giving the pupil a clear conception of the varying length of the day throughout the year in various latitudes. See Fig. 15.

Set the globe in the sunshine so that the light covers it from pole to pole. It is now falling perpendicularly upon the equator, as may be shown by standing a pencil or other object on the equator vertically with respect to the globe. It casts no shadow. This is the condition September 23d and March 21st.

Now place two chalk spots upon the globe in different latitudes but upon the same meridian. They represent two persons. Turn the globe and they will be seen to enter the shadow simultaneously and emerge simultaneously. This shows that with the sun over the equator the days are of equal length in all latitudes. The nights also are of equal length.

Moreover, it will be seen that the path traversed by each of these points crosses twelve hour circles in the light portion and the same in the dark. The days are equal to the nights. This is the season of the equinox.

To show why winter days are short in northern latitudes, tilt the globe so that the sunshine falls 23½° short of the north pole. Show as before that the sun is now vertical at the tropic of Capricorn. This represents December 22d. Leave the chalk spots placed as they were before. Now turn the globe, and the more northern one is seen to enter the shadow sooner than the one farther south. Sunset in that latitude comes earlier; the day is shorter. To determine by how much the day is shorter, count the hour spaces as before.

By similar demonstration the northern summer days can be shown to be long. The globe should now stand so that the sun shines 23½° past the north pole. See Fig. 15.

To show the reason for continuous day or night at certain seasons in the Arctic Circle: Place a chalk spot near the pole. On rotation of the globe while in the summer position, the spot does not enter the shadow at all. During rotation of the globe while in the winter position, the spot remains constantly in the shadow.

The length of day in the year in the observer's latitude (or elsewhere) may easily be found as follows:

By reference to the analemma, printed on most globes, ascertain the distance of the sun north or south of the equator upon that day. (Or, this information may be determined by the pupils, using the "sun board," Fig. 14.) Having obtained the position of the sun, set the globe so that the sun's rays shall fall vertically in that latitude and then proceed as above to find the length of day and night in the observer's latitude.

Difference of Temperature in Different Zones.—That the torrid zone is hot because of its vertical sun has but little educational significance, unless we teach why it is that vertical rays are hotter than those which are slanting as in the frigid zones.

The false impression prevails that vertical rays beat down with more force, or that the slanting rays glance off.

A simple diagram will make the matter clear.

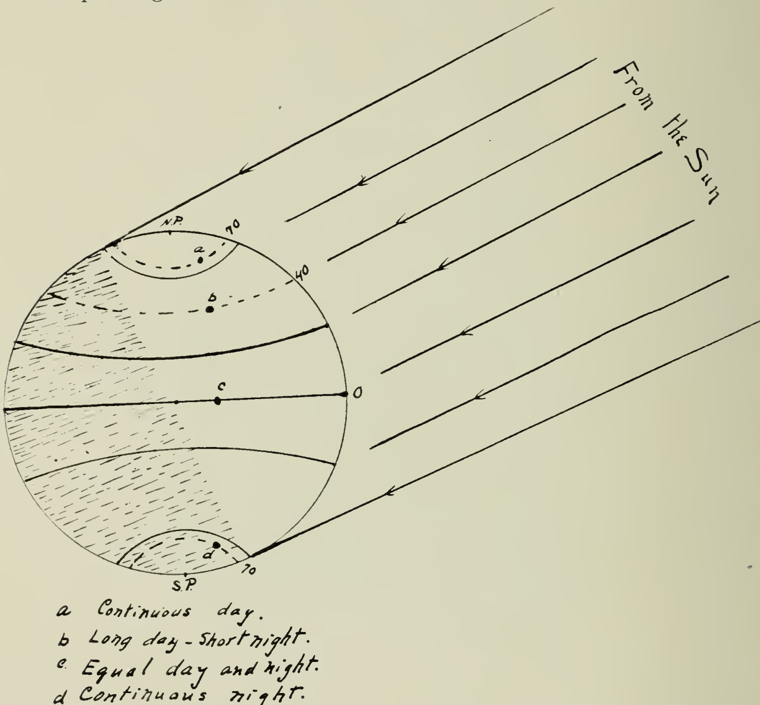

FIG. 15.—Diagram of a globe standing in the sunshine. A method of showing the effect of latitude and season upon relative length of day and night.

In Fig. 16 let *Sab* and *Scd* be two cones of rays of equal size and therefore of equal amounts of heat from the sun. The slanting cone *Sab* is distributed over more surface, as shown by the diagram, than the vertical cone *Scd,* and therefore the heat in any point in *ab* is less intense than in *cd.*

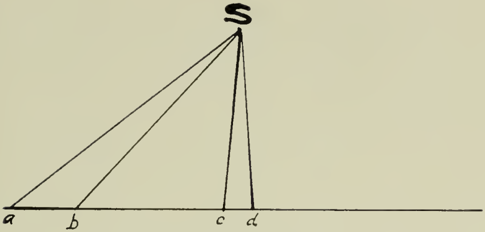

FIG. 16.—Showing why perpendicular rays are hotter than slanting rays.

The Planets.—Little special information about individual planets need be given, but the thought of their similarity to the earth should be made distinct. They should be studied rather as constituting the solar system than as individual objects of interest.

Observation.—Encourage evening study of the "wandering stars," as the ancients called the planets. Find from an almanac those visible;

FIG. 17.—Fixed stars and a moving planet. Let pupils make two such drawings from nature, with an interval of several weeks between.

make a sketch showing position with reference to several conspicuous stars near by. A few weeks later compare the planets' positions with those shown by the diagram.

For example suppose Venus, which is often visible as the brightest object in the western sky, is seen to be in a position such as is represented in "A," Fig. 17. Some days or weeks later it will have moved and may occupy a position relative to the stars, like that shown in "B." The stars, however, will be seen to be *fixed* with reference to one another.

Discuss the cause of this motion among the stars.

It takes Jupiter, the outermost planet which is plainly visible, twelve years to pass once around the sun. How many degrees does it move annually among the stars?

The Moon.—Refer to Fig. 11 for the position and motion of the moon relative to the other members of the solar system.

This diagram shows only the motion of the moon with reference to the earth.

It also moves with the earth about the sun once a year, making about twelve revolutions around the earth while the earth *and* moon are going once around the sun (twelve months in the year).

Use the model of the solar system, Fig. 12, to show this double motion.

The monthly revolution of the moon about the earth may be observed. It produces the eastward motion of the moon among the stars.

Establish first by observation that all of the heavenly bodies appear to move once about the earth each day from east to west, making sun, moon, and stars rise in the east and set in the west every 24 hours. But impress upon the pupils the fact that this motion is only apparent, and is caused by the earth's rotation on its axis.

Teach the fact that the eastward motion of the moon among the stars is a real motion of about 30° a day.

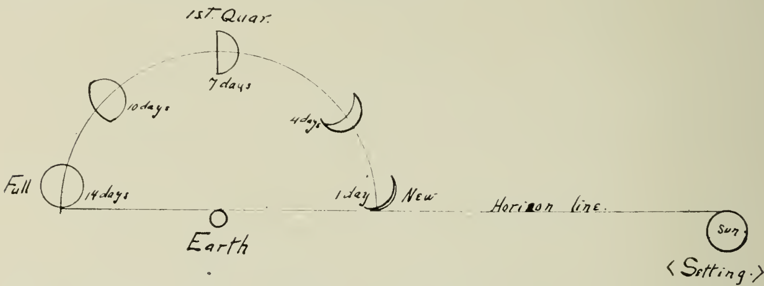

FIG. 18.—The moon's phases. Suggestion of diagram to be made from nature by pupils

The Moon's Phases.

Have pupils draw a "progressive diagram" which shall resemble Fig. 18 when finished.

To explain the cause of change of phase is simple, if, indeed, necessary after such a drawing has been completed.

The educational value of a drawing made from nature is greater than that of a copy made from a book.

Find from a calendar when a new moon may be expected, and upon that evening at sunset draw the moon showing its shape and position relative to the sun as seen in Fig. 18.

On successive days for two weeks add to this drawing the new form and position of the moon at sunset.

Why does the full moon always rise at sunset?

Mark the age of the moon in each case.

The eastward motion of the moon about the earth once in four weeks should be discussed.

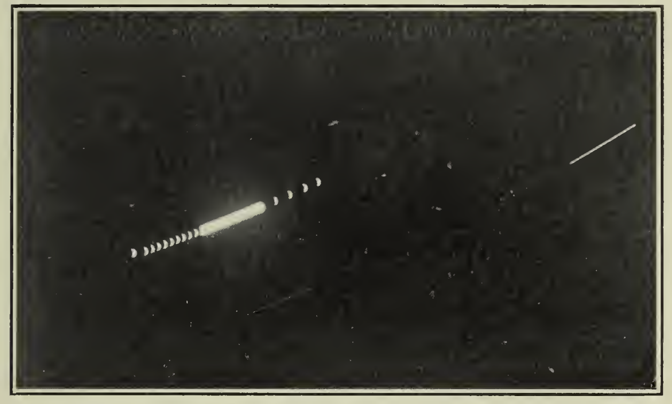

Fig. 19.—Kodak picture of the moon and Venus. Ten exposures of five seconds each at intervals of about two minutes; then a twenty-minute exposure, followed by four exposures at five-minute intervals.

Additional concreteness may be given this subject, however, by painting a ball half white and half black to represent light and darkness on the surface of the moon. Then, holding the ball in various positions before the class, let them see the crescent, the half circle, the full circle, and other intermediate forms which are assumed by the illuminated portion of the moon as it goes through its various phases.

Eclipses of Sun and Moon.—The cause of eclipses can be made clear by means of a diagram. See Fig. 20.

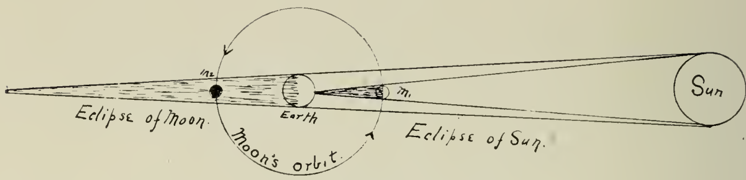

FIG. 20.—The cause of eclipses.

When the moon is between earth and sun, as at m_1 (Fig. 20) its shadow falls on a small part of the earth and the sun's light is eclipsed for the people living within the region of the shadow.

When the moon is beyond the earth from the sun, as at m_2, it passes through the earth's shadow and is eclipsed for all the people on that side of the earth.

The moon would be eclipsed once a month but that it usually passes in front of or behind the shadow, not through it.

Solar and lunar eclipses are about equally frequent.

Why is a solar eclipse so rare? A glance at Fig. 20 will show that shadow causing the solar eclipse falls on a very small portion of the earth's surface and is therefore visible to but few people, whereas the people on half of the earth's surface see every eclipse of the moon.

Comparison of the Moon With the Earth.—A consideration of some of the differences between the moon and the earth will help us to appreciate certain laws of nature as we see them upon earth.

The moon being smaller than the earth, the force of gravity there is one ninth what it is here.

How much would an average man weigh if on the moon?

If he can jump two feet high here, how high could he jump there?

Steeper mountain slopes can stand on the moon than would be possible here where the weight of the rocks tears them loose, thus helping to level our mountains. The lunar mountains are steep and rugged.

The moon is uninhabitable by beings like ourselves for lack of air and water, these vapors having flown away from it by reason of their lightness. The earth holds its air by force of gravity.

As the moon has no clouds or water vapor or air, the sun beats fiercely upon its barren surface, heating it intensely. The heat escapes at night, for it is not retained by a blanket of air; and the lunar night is probably colder than any portion of the earth in winter.

The moon rotates upon its axis once in about thirty days; thus its day and night are each of two weeks' duration.

How would such days inconvenience us?

The Ti[illegible] raises t[illegible]des.—Our tides are produced chiefly by the moon. It high ti[illegible]wo great tidal waves which sweep around the world bringing and [illegible]de to every coast twice a day. Many things, such as continents [illegible] shallow water, interfere with these waves; the sun also has an [illegible]pon the tides. But the action of these minor forces may be [illegible]d in a class discussion of tides.

[illegible]21 represents the action of the moon upon the waters surround-[illegible]e earth. The attractive force of the moon upon the water at *a* [illegible] greater than the force with which it draws the earth, because the water is nearer to the moon than is the earth. The water at *c*, however, is drawn with less force by the moon than is the earth; therefore, the earth is drawn away from the water which is left heaped, as at *a*. At *b* and *d* the water flows away to supply the tidal waves *a* and *c*; thus low tide occurs at *b* and *d*.

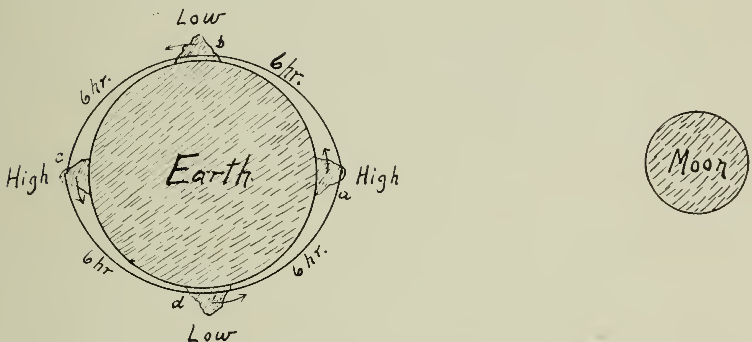

FIG. 21.—The cause of tides. The clear space represents the water of the oceans encircling the earth. *a, b, c,* and *d* are successive positions which an island or continent occupies as it is carried around by the earth's daily rotation, passing, at intervals of six hours, through regions of high and low tide.

We may think of the moon as passing around the earth once a day (as it seems to do and the tides following it, or we may think of the moon as standing almost still, as it really does, holding the tides stationary below it, while the earth turns giving to any particular place on its surface high and low tides alternately.

Thus, in Fig. 21, if a certain island or continent is at *a,* it is in a region of high tide, but six hours later when the earth by its rotation has carried it round to *b,* it is in the region of low tide. Six hours later it passes through high tide (*c*), and six hours thereafter it is at *d* (low tide), and comes around to the original high tide after the lapse of about a day.

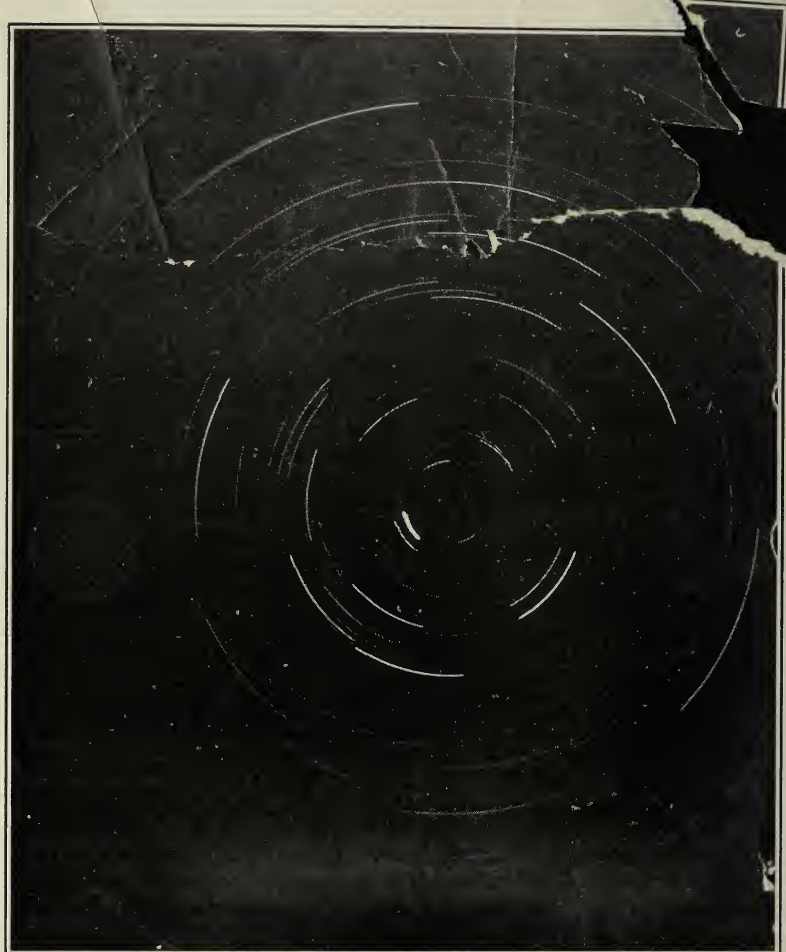

FIG. 22.—Star trails in the north polar regions. Such a picture, though fainter, can be made with a kodak. This picture was made with an improvised camera consisting of a stereopticon lens mounted in one side of a small goods box having a hole cut in the opposite side for a plate-holder. The time of exposure was two and one half hours.

Such a picture, made by teacher or pupils, is a very instructive demonstration of the apparent motion of the heavens—the real motion of the earth. Notice that the "north star" (the very bright one) is some distance (1¼°) from the true pole.

ars.—That stars are suns—apparently small and dim be- heir great distance—is the first lesson for pupils to learn. r what a sun is. It is large, intensely hot, gives light of the center around which revolve planets such as our

stars have their systems of planets, possibly inhabited; being so far away and having no light of their own, t visible to us.

An illustration of the distance to the stars will help to make the facts above comprehensible.

If we use the blackboard diagram mentioned in the discussion of the solar system in which one foot is taken as the distance of the sun to the earth and thirty feet as the distance to Neptune (the outermost planet of the solar system), the distance to the nearest star will be fifty miles. The North Star on the same scale would be 500 miles from the earth.

These vast distances account for the fact that the stars do not seem to move about among themselves. Their only apparent motion is that caused by the rotation of the earth which makes them rise and set. Unlike the planets the stars are "fixed." An illustration will make the cause of this evident.

When ships are seen far out at sea or animals are observed at a distance of several miles, it is impossible unless we watch for some time to tell if they are moving.

A life time is not long enough to ascertain if the stars move. Astronomers have means of finding that they are in rapid motion in all directions; but the relative position of stars to one another in the constellations has been what it is now for thousands of years.

The Constellations.—The names of some of the more distinct constellations should be learned and the pupils taught to recognize them. A few evening sessions of the class are advisable.

Young's *Uranography*, a booklet priced at 30 cents and published by Ginn & Co., gives good maps of the constellations and some account of each as well as of the principal stars of the constellations.

The following constellations are easily identified:

The Big Dipper (Ursa Major), Cassiopeia, Orion (after November), Canis Major, Canis Minor, The Sickle, and the Pleiades during the spring.

A fine set of maps, one for each month, can be secured by subscribing for the *Monthly Evening Sky Map*, published at Columbia University

for $1.00. This four-page publication contains a good deal tion aside from the maps. The stars, being in the same pos. cessive years, a set of these maps would become a perm atlas.

The following books are sufficiently popular in style to the teacher who wishes to become informed up astronomy. They are standard works and easily fou

Star Land, (Ball), Ginn & Co.		
Giant Sun and His Family, (Proctor), Silver, Burdette Co.		
Other Worlds, (Serviss), Appleton	1	20
Lesson in Astronomy, (Young), Ginn & Co.	1	25
Elements of Astronomy, (Ball), MacMillan		80
New Astronomy, (Todd), American Book Co.	1	30

The first three books mentioned are easily within the comprehension of grammar grade children, and are interestingly written.

If the course has given the class a desire to read such books as the above and to continue the observations which have been begun in school, it will have accomplished its end—to bring the child into intelligent sympathy with nature.